CLAIMS

[1] A reception device for receiving a transmission frame including a synchronization symbol string, having a synchronization symbol repeated a plurality of times, inserted before a data symbol string, wherein:

the synchronization symbol is a symbol obtained by synthesizing a plurality of sub band symbols which are orthogonal to each other and having different carrier frequencies;

the carrier frequencies of the plurality of sub band symbols are located at an equal predetermined frequency interval;

the synchronization symbol includes a synchronization pattern repeated at an interval of a reciprocal of the predetermined frequency interval;

the reception device comprises:

a clock generation unit for generating a sampling clock;

an analog/digital converter for sampling the transmission frame based on the sampling clock generated by the clock generation unit and analog/digital-converting the transmission frame;

a frequency correction unit for correcting a frequency of an output from the analog/digital converter;

a synchronization pattern correlation unit for obtaining a correlation between the output from the frequency

correction unit and the synchronization pattern, and outputting the correlation as a synchronization pattern correlation value;

a peak detection unit for detecting a peak of the output from the synchronization pattern correlation unit, and outputting the peak as a peak timing;

a timing determination unit for outputting a predetermined timing in the synchronization symbol based on the peak timing which is output from the peak detection unit;

an inter-synchronization pattern phase difference detection unit for detecting a change amount of a phase of the synchronization pattern correlation value which is output from the synchronization pattern correlation unit in accordance with the output from the timing determination unit and the peak timing which is output from the peak detection unit, and estimating an error of the frequency of the output from the analog/digital converter based on the change amount of the phase of the synchronization pattern correlation value;

a plurality of sub band correlation units each for obtaining a correlation between a sub band symbol assigned thereto, among the plurality of sub band symbols, and the output from the frequency correction unit, and outputting the correlation as a sub band correlation;

an inter-symbol phase difference detection unit for obtaining a phase difference at a predetermined symbol interval of the sub band correlation which is output from each

of the plurality of sub band correlation units in accordance with the output from the timing determination unit, outputting the phase difference as an inter-symbol phase difference, and estimating an error of the frequency of the output from the analog/digital converter based on the inter-symbol phase difference;

an inter-sub band phase difference detection unit for detecting a phase difference, among the sub bands, of the inter-symbol phase difference which is output from the inter-symbol phase difference detection unit as an inter-sub band phase difference in accordance with the output from the timing determination unit, and estimating an error of the sampling clock based on the detected inter-sub band phase difference; and

a data demodulation unit for demodulating the output from the frequency correction unit in accordance with the output from the timing determination unit;

the frequency correction unit corrects the frequency of the output from the analog/digital converter based on the frequency error estimated by the inter-synchronization pattern phase difference detection unit, and then corrects the frequency of the output from the analog/digital converter based on the frequency error estimated by the inter-symbol phase difference detection unit; and

the clock generation unit corrects a frequency of the sampling clock based on the error estimated by the inter-sub band phase difference detection unit.

[2] A reception device according to claim 1, wherein the timing determination unit outputs a start timing of the synchronization symbol string when the peak timing which is output from the peak detection unit is detected at the synchronization pattern interval a predetermined number of times, and outputs a termination timing of the synchronization symbol string when the peak timing stops being detected at the synchronization pattern interval.

[3] A reception device according to claim 2, wherein the inter-synchronization pattern phase difference detection unit averages the change amounts of the phase of the synchronization pattern correlation value, estimates the frequency error of the output from the analog/digital converter, and when the start timing is output from the timing determination unit, terminates the averaging and inputs the estimated frequency error to the frequency correction unit.

[4] A reception device according to claim 2, wherein when the start timing is output from the timing detection unit, the inter-symbol phase difference detection unit averages the inter-symbol phase differences and estimates the frequency error of the output from the analog/digital converter.

[5] A reception device according to claim 1, wherein the inter-symbol phase difference detection unit shortens the predetermined symbol interval when the frequency error is large and extends the predetermined symbol interval when the frequency error is small.

[6] A reception device according to claim 1, wherein the inter-sub band phase difference detection unit averages the inter-sub band phase differences and estimates the error of the sampling clock.

[7] A reception device according to claim 1, wherein the data symbol string is multicarrier-modulated using an orthogonal wavelet function.

[8] An integrated circuit for receiving a transmission frame including a synchronization symbol string, having a synchronization symbol repeated a plurality of times, inserted before a data symbol string, wherein:

the synchronization symbol is a symbol obtained by synthesizing a plurality of sub band symbols which are orthogonal to each other and having different carrier frequencies;

the carrier frequencies of the plurality of sub band symbols are located at an equal predetermined frequency interval;

the synchronization symbol includes a synchronization

pattern repeated at an interval of a reciprocal of the predetermined frequency interval;

the reception device comprises:

a clock generation unit for generating a sampling clock;

an analog/digital converter for sampling the transmission frame based on the sampling clock generated by the clock generation unit and analog/digital-converting the transmission frame;

a frequency correction unit for correcting a frequency of an output from the analog/digital converter;

a synchronization pattern correlation unit for obtaining a correlation between the output from the frequency correction unit and the synchronization pattern, and outputting the correlation as a synchronization pattern correlation value;

a peak detection unit for detecting a peak of the output from the synchronization pattern correlation unit, and outputting the peak as a peak timing;

a timing determination unit for outputting a predetermined timing in the synchronization symbol based on the peak timing which is output from the peak detection unit;

an inter-synchronization pattern phase difference detection unit for detecting a change amount of a phase of the synchronization pattern correlation value which is output from the synchronization pattern correlation unit in accordance

with the output from the timing determination unit and the peak timing which is output from the peak detection unit, and estimating an error of the frequency of the output from the analog/digital converter based on the change amount of the phase of the synchronization pattern correlation value;

a plurality of sub band correlation units each for obtaining a correlation between a sub band symbol assigned thereto, among the plurality of sub band symbols, and the output from the frequency correction unit, and outputting the correlation as a sub band correlation;

an inter-symbol phase difference detection unit for obtaining a phase difference at a predetermined symbol interval of the sub band correlation which is output from each of the plurality of sub band correlation units in accordance with the output from the timing determination unit, outputting the phase difference as an inter-symbol phase difference, and estimating an error of the frequency of the output from the analog/digital converter based on the inter-symbol phase difference;

an inter-sub band phase difference detection unit for detecting a phase difference, among the sub bands, of the inter-symbol phase difference which is output from the inter-symbol phase difference detection unit as an inter-sub band phase difference in accordance with the output from the timing determination unit, and estimating an error of the sampling clock based on the detected inter-sub band phase difference; and

a data demodulation unit for demodulating the output from the frequency correction unit in accordance with the output from the timing determination unit;

the frequency correction unit corrects the frequency of the output from the analog/digital converter based on the frequency error estimated by the inter-synchronization pattern phase difference detection unit, and then corrects the frequency of the output from the analog/digital converter based on the frequency error estimated by the inter-symbol phase difference detection unit; and

the clock generation unit corrects a frequency of the sampling clock based on the error estimated by the inter-sub band phase difference detection unit.

[9] A method for receiving a transmission frame including a synchronization symbol string, having a synchronization symbol repeated a plurality of times, inserted before a data symbol string, wherein:

the synchronization symbol is a symbol obtained by synthesizing a plurality of sub band symbols which are orthogonal to each other and having different carrier frequencies;

the carrier frequencies of the plurality of sub band symbols are located at an equal predetermined frequency interval;

the synchronization symbol includes a synchronization pattern repeated at an interval of a reciprocal of the predetermined

frequency interval; and

the method comprises:

sampling and analog/digital-converting a transmission frame;

obtaining a correlation between the analog/digital-converted signal and the synchronization pattern, and setting the correlation as a synchronization pattern correlation value;

detecting a peak of the synchronization pattern correlation value, and setting the peak as a peak timing;

detecting a predetermined timing in the synchronization symbol based on the peak timing;

detecting a change amount of a phase of the synchronization pattern correlation value in accordance with the predetermined timing and the peak timing, and estimating an error of a frequency of the output from an analog/digital converter based on the change amount of the phase of the synchronization pattern correlation value;

obtaining a correlation between each of at least two sub band symbols, among the plurality of sub band symbols, and the signal with the frequency corrected, and setting the correlations as at least two sub band correlations;

obtaining a phase difference at a predetermined symbol interval of each of the sub band correlations in accordance with the predetermined timing, and setting the phase difference

as an inter-symbol phase difference;

estimating an error of the frequency of the output from the analog/digital converter based on the inter-symbol phase difference;

setting a phase difference, among the sub bands, of the inter-symbol phase difference in accordance with the predetermined timing as an inter-sub band phase difference;

estimating an error of the sampling clock based on the inter-sub band phase difference;

correcting the frequency of the analog/digital-converted signal based on the error of the frequency estimated based on the change amount of the phase of the synchronization pattern correlation value;

correcting the frequency of the analog/digital-converted signal based on the error of the frequency estimated based on the inter-symbol pattern phase difference;

correcting the frequency of the sampling clock based on the error of the sampling clock estimated based on the inter-sub band phase difference; and

demodulating the corrected analog/digital-converted signal.